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HYDROGRAPHIC AND ECOLOGICAL EFFECTS OF ENLARGEMENT OF THE CHESA--ETC(U)
SEP 73 R P MORGAN, V J RASIN, L A NOE DACW61-71-C-0062
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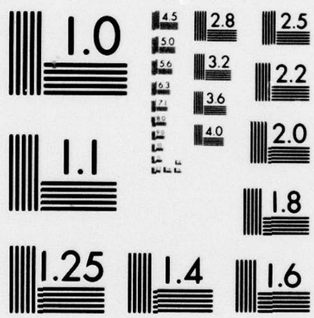
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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Appendix XI 6 -VI	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Hydrographic and ecological effects of enlargement of the Chesapeake and Delaware Canal. Appendix XI. Effects of suspended sediments on ~~dev.~~ the development of eggs and larvae of striped bass and ~~perch~~ White Perch.		5. TYPE OF REPORT & PERIOD COVERED App. 1971-72
		6. PERFORMING ORG. REPORT NUMBER N. R.J. REF no. 73-110
7. AUTHOR(s) Morgan, Raymond P. ~~II~~ Rasin, V. James Jr. Noe, Linda A.	15	8. CONTRACT OR GRANT NUMBER(s) DACW61-71-C-0062
9. PERFORMING ORGANIZATION NAME AND ADDRESS Natural Resources Institute Chesapeake Bilogical Laboratory U. of Maryland Center for Environmental & Estuarine St.		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army, Corps of Engineers Philadelphia Dist. Customs House, 2nd & Chestnut Sts. Phila. Pa. 19106	11	12. REPORT DATE Sep[redacted]973 13. NUMBER OF PAGES 21
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 12 31p.		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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14 NRI-REF-73-110

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

10 Raymond P./Morgan, II,
V. James/Rasin, Jr.
Linda A./Noe

18. SUPPLEMENTARY NOTES

9 Rept. for 1971-1972,

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Chesapeake & Delaware Canal	Fish larvae
Striped bass	Salinity
White perch	Suspended sediments

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Experiments on suspended sediments and fish larvae were undertaken. Bioassays on stiped bass and white perch larvae and exposure to seston levels were performed. Results are given.

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APPENDIX XI.

Effects of Suspended Sediments on the Development of Eggs and Larvae of Striped Bass and White Perch[1]

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NRI Ref. No. 73-110

INTRODUCTION

Pritchard and Cronin (1971) have predicted that enlargement of the Chesapeake and Delaware (C and D) Canal, from 8.2 m (27 ft) by 76.2 (250 ft) to 10.7 m (35 ft) by 137.2 m (450 ft), will result in increased average maximum tidal velocities of about 0.69 m/sec (2.28 ft/sec), a factor of 1.23. This increased flow, along with natural sediment input and maintenance dredging, may create higher suspended sediment loads in the canal and its approaches.

The possible ecological effects of suspended sediments are manifold. Briefly, suspended sediments may cause an increased surface for microorganism growth, fewer temperature fluctuations, chemical adsorption or absorption, blanketing, mechanical-abrasive actions, and light penetration reduction (Cairns, 1968). Sherk and Cronin (1970) have pointed out that the above effects have been little studied in the estuarine environment.

The ecological effects of suspended sediments on fish eggs and larvae may be of prime importance to the C and D Canal area, an important spawning and primary nursery area for a variety of estuarine species (Johnson, 1972). This section discusses the effects of suspended sediment on the eggs and larvae of striped bass and white perch.

Materials and Methods

Suspended sediment assays were performed using an apparatus that basically followed the design of Schubel, Schiemer and Schmidt (1972), except that we used a 25 RPM motor instead of an 18 RPM motor for driving the plate and we did not use the feeder reservoir. The build-up of waste products (excretion from the eggs and larvae of nitrogenous wastes) was nonsignificant in relation to the egg:water volume ratio. Behavior of the suspended solids in our tanks basically followed the type of variation noted by Schubel et al. (1972) in their tanks.

The sediment used in all of our experiments was collected from the western end of the canal and was essentially silt and clay. Instead of drying the sediment, which might change its colloidal nature, it was kept hydrated. To ensure dispersion of any aggregates that might have formed, the sediment was sonified for 15 min with a Biosonik IV sonifier after being placed in the sediment chamber. The concentration of sediment was measured in triplicate for each tank by taking aliquots of the suspended sediment and filtering it through pre-weighed 0.5 μ Nucleopore filter membranes. The membranes were dried over silica gel for 48 hrs in a desiccator and then weighed. The coefficients of variation for the suspended sediment analyses were generally less than one per cent.

The eggs were not allowed to float freely in each exposure bath but were incubated in plexiglas cylinders, the bottom of which were covered with fine mesh nitex screen. Larvae were also assayed in these cylinders.

Each sediment tank was placed in a large plexiglas tank. Temperature was controlled with a Blue-M portable cooling coil and a Braun heater-circulator in the external bath.

The effect of sediment blanketing on white perch eggs (an adhesive demersal egg) was studied by mixing up various sediment concentrations and then pouring the solution over white perch eggs that had been water-hardened in TPX dishes. This technique allowed us to prepare triplicate samples with ease. The sediment settled uniformly over the eggs and the thickness of the sediment was easily measured with a vernier caliper or metric rule. Triplicate samples for a variety of sediment thicknesses were incubated in a large bath with temperature controls.

Eggs and larvae for the sediment experiment were obtained as described in Morgan and Rasin (1973). Eggs and larvae were scored according to the

ranking scale used in temperature and salinity experiments (Morgan and Rasin, 1973). Per cent hatch and survival were determined for each sample. Statistical tests were from Sokal and Rohlf (1969).

RESULTS

Both the eggs of white perch and striped bass are resistant to the effects of suspended sediments. White perch eggs were exposed to suspended sediment levels ranging from 50 to 5250 ppm (Fig. 1). Per cent hatch was not significantly affected over the range of sediment levels tested (Fig. 1). However, the development rate of the white perch eggs was significantly ($p = 0.05$) slowed at sediment levels over 1500 ppm (Fig. 1). At 5250 ppm, the developmental rate was lowered to approximately 65% of the control. The developmental rates from 4000 - 5250 ppm were significantly lower than the rates from 2000 to 3250 ppm. All the development rates from 2000 to 3250 ppm were approximately 80 - 85% of the control development. These lowered developmental rates, at higher sediment levels, delayed hatch of the white perch eggs by as much as one day.

The hatch of striped bass eggs, as per cent of control hatch, was not significantly affected by suspended sediment levels ranging from 20 to 2300 ppm (Fig. 2). Striped bass hatch at sediment levels of 900 to 1050 ppm was low (42-52 per cent of control hatch), but the standard deviations for each point of three replicates was about 35 per cent of the mean. Generally, the standard deviations for all of the other points were lower than 15 per cent of the mean.

Development of the striped bass eggs was significantly ($p = 0.05$) lowered at sediment levels over 1500 ppm (Fig. 2). The developmental

rate was lowered to approximately 80% of the control ranked development.

In the majority of experiments with both white perch and striped bass, we did not observe sediment sticking to the eggs until sediment levels of over 1000 ppm were reached. This may be an artifact of the testing equipment or our preservation techniques. Even at 2300 ppm of sediment, there was little sediment adhering to the striped bass eggs. Generally, white perch eggs exposed to suspended sediment levels over 2000 ppm had more adhering sediment than did the striped bass eggs.

White perch eggs are adhesive and demersal (Mansueti, 1964). Consequently, suspended sediments (which do not seem to influence per cent hatch) may not be as important as the effect of deposition of sediment on eggs that had recently been spawned. White perch eggs measured 0.89 mm from the field and 0.92 mm from artificial spawning, with ranges of 0.75 - 1.04 mm (Mansueti, 1964). We found a mean diameter of 0.86 mm for artificially spawned white perch (Morgan and Rasin, 1973).

We will use the value of 0.90 mm for the diameter of white perch eggs. Blanketing of white perch eggs by sediment greater than 2 mm in thickness (a covering of 1.2 mm over the top of the egg) resulted in 100% mortality (Fig. 3). Sediment thickness of 0.5 mm to 1.0 mm also caused significant mortalities greater than 50%. Sediment blanketing of below 0.45 mm (the bottom half or less of an egg would be in the sediment) does not result in significant mortalities (Fig. 3).

Developmental rates of white perch eggs were lowered significantly at a sediment thickness of over 0.8 mm. In those eggs that had been exposed to a sediment thickness of 2 mm or greater, development was less than 60% of the control. The majority of eggs died at the late morula-early gastrula stage.

The effects of high suspended sediment levels on striped bass and white perch larvae were determined by a series of acute bioassays. Generally, these assays were either of a one or two-day exposure. Some 6-hr exposures of larvae to high sediment levels were also run, but these short exposures, even to suspended sediment levels of 5200 ppm, did not result in detectable mortality for either striped bass or white perch larvae.

Levels of 1626 to 5380 ppm of suspended sediment resulted in white perch larval mortality ranging from 27.3 to 29.3 per cent (Fig. 4) for a one-day exposure. There was a significant linear regression of mortality versus seston concentration (Table 1) after pooling the sums of squares attributed to deviations from regression and the error sum of squares. The significant deviations from regression (for three of the sediment bioassays) were a result of either heterogeniety around the regression line or a possible curvelinear function rather than a linear function (Sokal and Rohlf, 1969). One possible way to eliminate some of these significant deviations from regression would have been to have more experimental values in the lower seston ranges.

White perch exposed to seston levels of 1626 to 5380 ppm for two days had mortality rates of 22.6 to 62.0 per cent (Fig. 4). Again there was a significant linear regression (Table 1) of larval mortality to seston level.

Calculation of the LD_{50} for 1-day and for 2-day exposures from the regression equations indicated that seston levels of 11,642.4 ppm at one day and of 2679.5 ppm for two days would kill 50 per cent of a larval white perch population.

Similar results were obtained for the effects of suspended sediment on larval striped bass (Fig. 5). Sediment levels from 1557 to 5210 ppm caused striped bass mortalities ranging from 20.0 to 27.3 per cent for a one-day exposure and 38.7 to 66.0 per cent for a two-day exposure. There was a significant regression of striped bass larval mortality to suspended sediment levels (Table 2) for both the one-and two-day exposures.

To kill 50 per cent of a larval striped bass population in one day, sediment loads of 7845.8 ppm must be present. The LD_{50} for a two-day exposure is 3411.0 ppm.

It should be pointed out now that all of the assays for sediment effects on either larval striped bass or white perch were simply acute bioassays. Longer exposures to lower suspended sediment concentrations could result in significant mortalities. It may be necessary to modify the experimental tanks, for either longer acute exposures or chronic experiments, by providing a food delivery system for the larvae.

DISCUSSION

At the present, there is little information on the effect of suspended materials on the development of fish eggs and larvae. Sherk (1971) comments on only four papers concerning fish eggs and larvae and either suspended or deposited sediments. One of these papers was by Bayliss (1968) who observed that striped bass eggs hatch better on "cleaner" types of bottom materials such as sand rather than mud. Obviously, striped bass eggs in nature seldom spend all of their time incubating on bottom materials but are carried by currents.

Recently, Schubel and Wang (1973) have studied the effects of suspended sediment on the per cent hatch of a number of estuarine spawners including the white perch and striped bass. They found that suspended sediment concentrations up to 500 ppm had no effect on the hatching success of white perch or striped bass and that there was a frequent delay in hatch of the eggs when exposed to sediment levels over 100 ppm. Our work at both comparable and higher levels of sediment support their conclusions (Fig. 1 and 2). However, development rate, expressed as per cent control ranked development, was always lower than control development even at 50 ppm sediment for striped bass (Fig. 2). We observed significant changes in per cent control ranked development at seston levels of approximately 2000 ppm and higher for white perch eggs (Fig. 1).

The C and D Canal is in a turbid area (Flemer, 1969). With permission from Dr. Jerry Schubel, CBI, we were able to examine some of his data for the C and D Canal region in 1971 (Table 3 and Fig. 6). We emphasized the stations for the March 1971 period. Values for the surface are generally lower than the seston levels at ten meters. Seston levels are high during the March period for all stations in the canal area and are considerably lower than those observed at Grove Point (Table 3). An extreme value of seston was observed on 11 March 1971 at CD 5 (Lorewood Grove) of 1043.5 ppm. Later in the year, a seston load of 2703.1 ppm was recorded at CD 3 at a depth of 11.5 m. (CD 3 is west of Summit Bridge.) These very high values may reflect dredging activities and not natural conditions.

We measured seston levels for selected stations in the canal area in 1972 (Fig. 6 and Table 4). The values were lower than those reported by Schubel for the same general area. However, we were sampling only at the surface. All but one of our observations were below 100 ppm, whereas Schubel's seston values tend to be higher.

The sediment load present in the canal, even during dredging operations, does not appear to be a factor influencing striped bass hatch and subsequent survival as larvae. Both the egg and larva are resistant to high sediment levels; however, we must qualify this statement by stating that long-term chronic exposures should be performed.

Typically, the white perch egg is demersal although it may be dislodged from its attachment. The sediment load in the canal does not affect the hatch of white perch. We feel that the amount of deposited sediment can influence per cent hatch of white perch as illustrated in Fig. 3. Again, we must point out that a significant egg mortality would have to be the result of sediment being deposited at a rate greater than 1 mm in about two days, the time to hatch from fertilization for white perch (Mansueti, 1964). White perch eggs can complete development and hatch even if completely covered by silt (Fig. 3). Larval white perch were also resistant to high suspended sediment concentrations. We feel that white perch eggs and larvae have evolved to a type of estuarine existence consistent with their spawning behavior. The demersal adhesive eggs of the white perch are constantly in contact with high sediment levels although tidal currents may serve to prevent suffocation of the eggs. The white perch egg is fixed to the substrate such that some abrasion from suspended sediments may occur.

Both Talbot (1966) and Mansueti (1961) have pointed out that striped bass are adapted to silt-laden and turbid waters. Again, the resistance of striped bass eggs and larvae to high suspended concentrations may be a factor in their success.

Presently, dredging operations may be adding to the sediment load in the canal region. With completion of the dredging except for maintenance, the seston levels may stabilize and become more subject to the physical characteristics of the canal area.

The canal area lies in a high turbidity area which is governed by freshwater input and climatological conditions. These factors probably govern the seston load in the upper Chesapeake Bay more than any influence from current dredging operations.

In the C and D Canal proper, the increased water velocity (Pritchard and Cronin, 1971) may contribute to maintaining a higher seston load in the canal and its approaches. However, the higher seston load may lower the mortality of the striped bass larvae. The decreased visibility from the seston in the canal area may result in less predation in the striped bass larvae.

ACKNOWLEDGMENTS

We wish to thank all of the people who assisted us during this study. However, the views and the information assembled in this report are our sole responsibility.

Thanks go to Drs. L. Eugene Cronin, Ted S. Y. Koo, Robert K. Johnson, Joseph O'Connor, Jerry Schubel, and Robert Biggs. We wish to thank Melvin Beaven, John Cooper, Nona Henderson, Sue Morgan, Ruth Wilson, Fran Younger, Mike Reber, Andrew Auld, Jerry Cox, Tom Johnson, Charles Main, and Terry Peterson.

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Table 1. Analysis of variance for the regression of white perch larval mortality on suspended sediment concentration.

One-Day Exposure

Source	df	SS	MS	F[1]	FP[2]
Among	4	326.72	81.68	7.19	
Linear Regression	1	127.05	127.05	1.91 ns	5.27
Deviations from Regression	3	199.67	66.56	5.86	
Within (Error)	10	113.48	11.35		
Total	14	440.20			

Two-Day Exposure

Source	df	SS	MS	F[1]	FP[2]
Among	4	1225.38	306.34	13.03	
Linear Regression	1	901.52	901.52	8.35	20.96
Deviations from Regression	3	323.86	107.95	4.59	
Within (Error)	10	235.07	23.51		
Total	14				

[1] $F(4,10) = 3.48$; $F(1,10) = 4.96$; $F(3,10) = 3.71$; at 5%level of probability.

[2] FP = F value for linear regression after the sums of squares for deviations from regression and within are pooled.

Table 2. Analysis of variance for the regression of striped bass larval mortality on suspended sediment concentration.

One-Day Exposure

Source	df	SS	MS	F[1]	FP[2]
Among	4	1062.53	265.63	14.93	
Linear Regression	1	684.16	684.16	5.42	15.98
Deviation from Regression	3	378.37	126.12	7.09	
Within (Error)	10	177.90	17.79		
Total	14				

Two-Day Exposure

Source	df	SS	MS	F[1]
Among	4	1495.15	373.79	23.79
Linear Regression	1	1425.74	1425.74	61.6
Deviations from Regression	3	69.41	23.14	1.47
Within (Error)	10	157.06	15.71	
Total	14			

[1] $F(4,10)=3.48$; $F(1,10)=4.96$; $F(3,10)=3.71$; at 5%level of probability.

[2] FP=F value for linear regression after the sums of squares for deviations from regression and within are pooled.

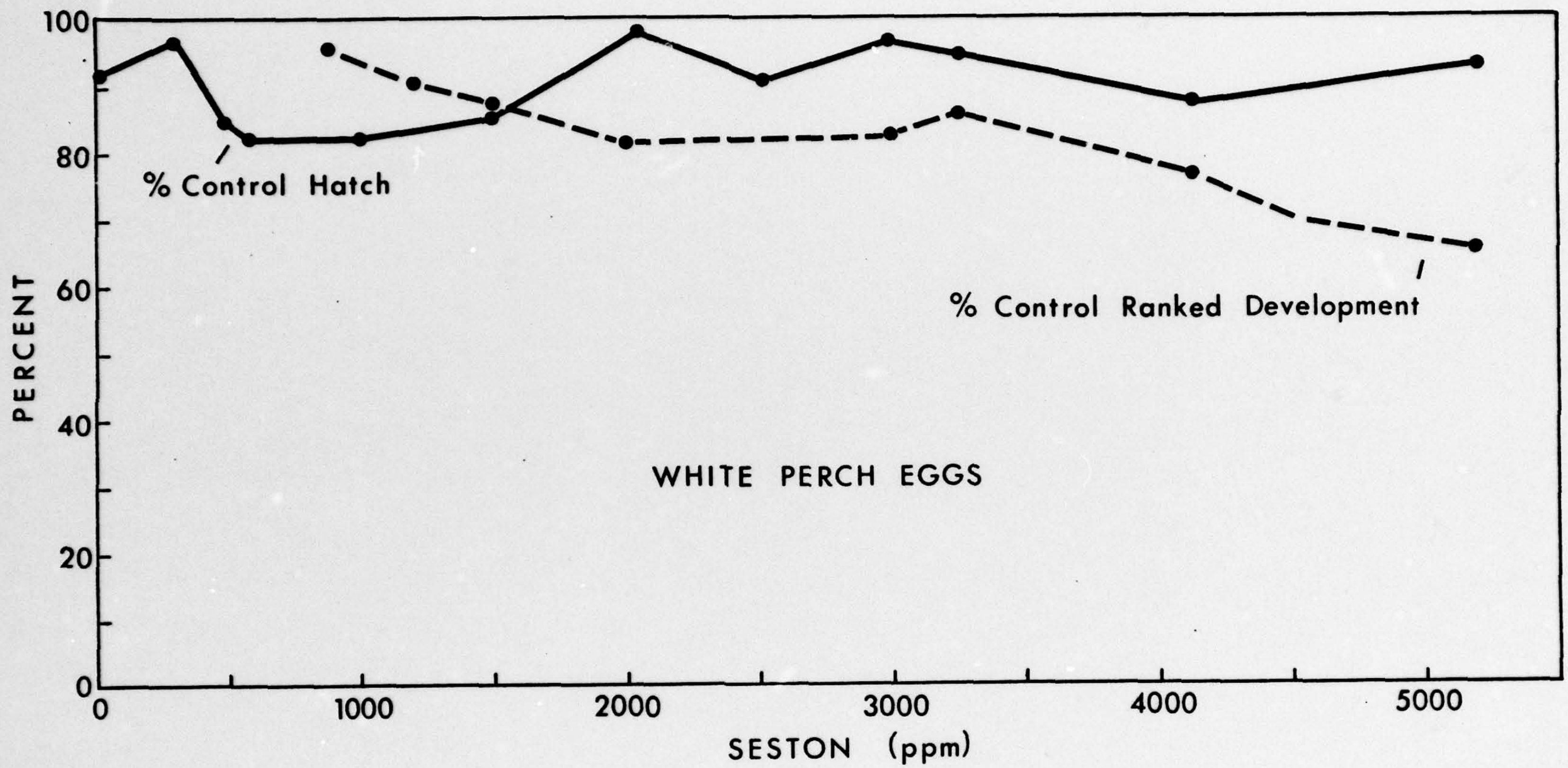
Table 3. Seston levels expressed as ppm for eight stations in the C and D Canal region taken during 1971 by Dr. Jerry Schubel, Chesapeake Bay Institute. The exact station locations are given in Fig. 6. The bottom depth was 10 meters.

Date	Depth	Station							
		Grove Pt.	Old Town Pt.	CD1	CD2	CD4	CD6	CD8	DR2
11 March 1971	Surface (S)	18.0	127.3	137.6	117.6	116.7	83.67	87.2	---
	Bottom (B)	62.7	185.7	190.2	269.3	225.6	194.0	---	---
23 March 1971	S	45.3	119.9	168.7	219.9	193.7	234.6	220.9	160.4
	B	108.6	163.5	302.9	340.2	422.5	348.5	190.7	392.9
25 March 1971	S	29.5	69.9	56.6	54.8	57.8	111.7	185.3	104.1
	B	53.5	77.3	90.1	84.2	86.9	245.4	240.2	139.5
30 March 1971	S	36.4	64.9	66.0	76.8	77.8	75.8	150.4	71.2
	B	42.6	105.9	110.7	105.5	116.4	---	---	106.5
18 August 1971	S	11.6	21.8	19.2	20.3	19.9	70.2	99.1	36.2
	B	33.7	41.9	29.3	25.5	46.1	265.3	144.6	119.6
19 October 1971	S	16.1	48.9	48.8	29.3	29.2	24.3	100.4	52.9
	B	18.6	210.1	311.9	190.2	35.1	181.1	907.7	133.4

Table 4. Seston levels in ppm for Chesapeake Biological Laboratory stations in the C and D Canal region for 1972. The station locations are shown in Fig. 6. All values are for surface samples.

Station	Date						
	27 Jan	1 Mar	16 Mar	27 Mar	4 Apr	6 June	15 June
E-1		50.6	60.1	25.4	23.0		15.7
E-3			71.8				
E-5		60.0	74.4	46.8		27.4	24.3
C-1					33.2	30.3	
C-2			72.1	19.6		19.9	95.0
C-4		58.9	68.6				
C-5				34.9		27.4	74.2
C-6			56.9				
C-8	68.0	86.5	63.3	33.6		35.4	249.3
R-10	50.2	51.4	62.5	54.1		35.0	40.2
C-27		41.8			46.5	150.1	
N2N					32.0	41.5	

Fig. 1. The effects of suspended sediment on the eggs of white perch expressed as per cent of control hatch and per cent of ranked development of the control group. Each point represents the mean of at least three replicates (in some cases, nine replicates). The coefficients of variation for all of the experiments were usually 10 per cent or less.



100
80
60
40
20
0
PERCENT
% Control Hatch
% Control Ranked Development
WHITE PERCH EGGS
0
1000
2000
3000
4000
5000
SESTON (ppm)

Fig. 2. The effect of suspended sediments on the eggs of striped bass expressed as per cent of control hatch and per cent of ranked development of the control group. Each point represents the mean of at least three replicates.

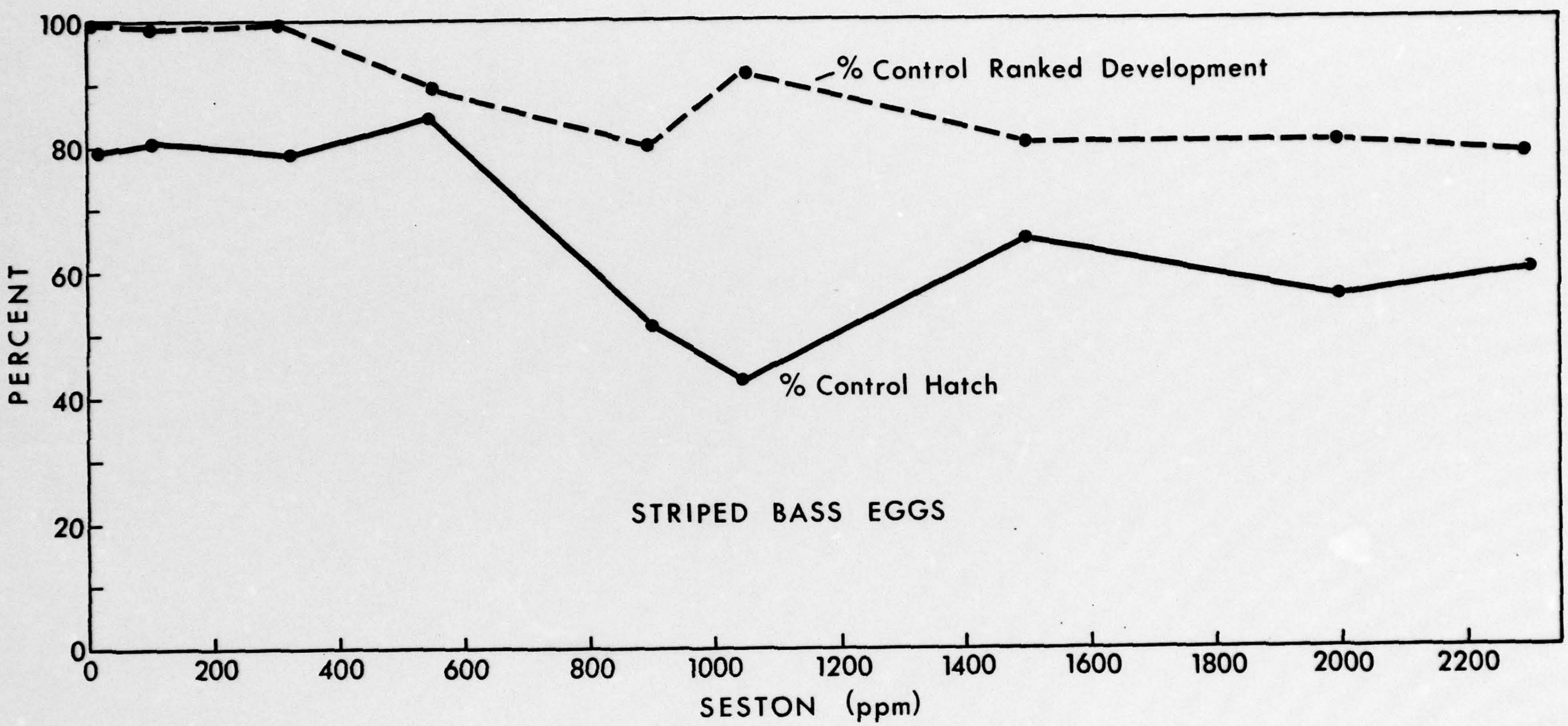

% Control Ranked Development
% Control Hatch
STRIPED BASS EGGS
PERCENT
SESTON (ppm)
0
20
40
60
80
100
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200

Fig. 3. The effects of sediment blanketing on white perch eggs expressed as per cent of control hatch and per cent of control ranked development. Each point is the mean of three replicates.

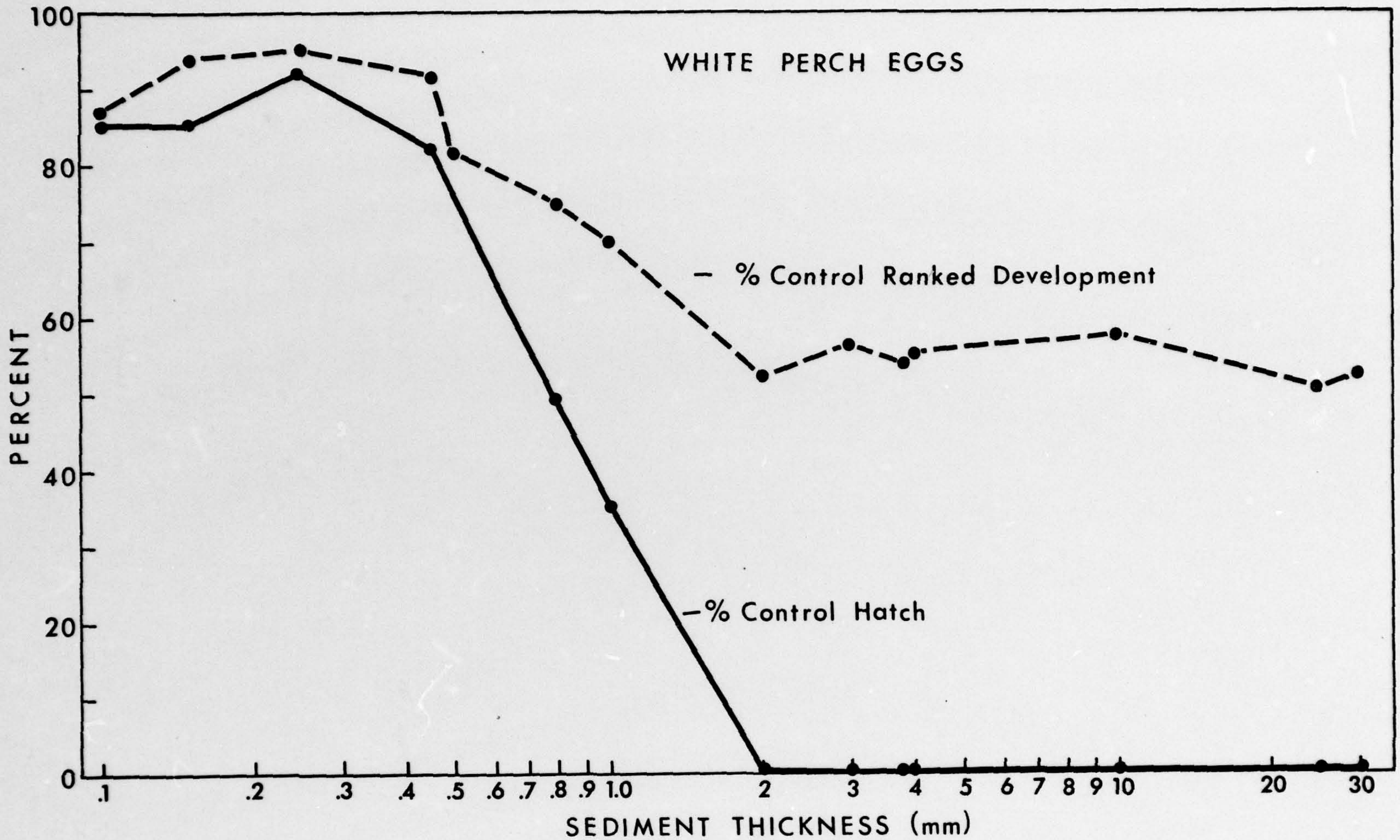

WHITE PERCH EGGS
% Control Ranked Development
% Control Hatch
PERCENT
100
80
60
40
20
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
2
3
4
5
6
7
8
9
10
20
30
SEDIMENT THICKNESS (mm)

Fig. 4. The effect of various suspended sediment concentrations on the per cent mortality of larval white perch.

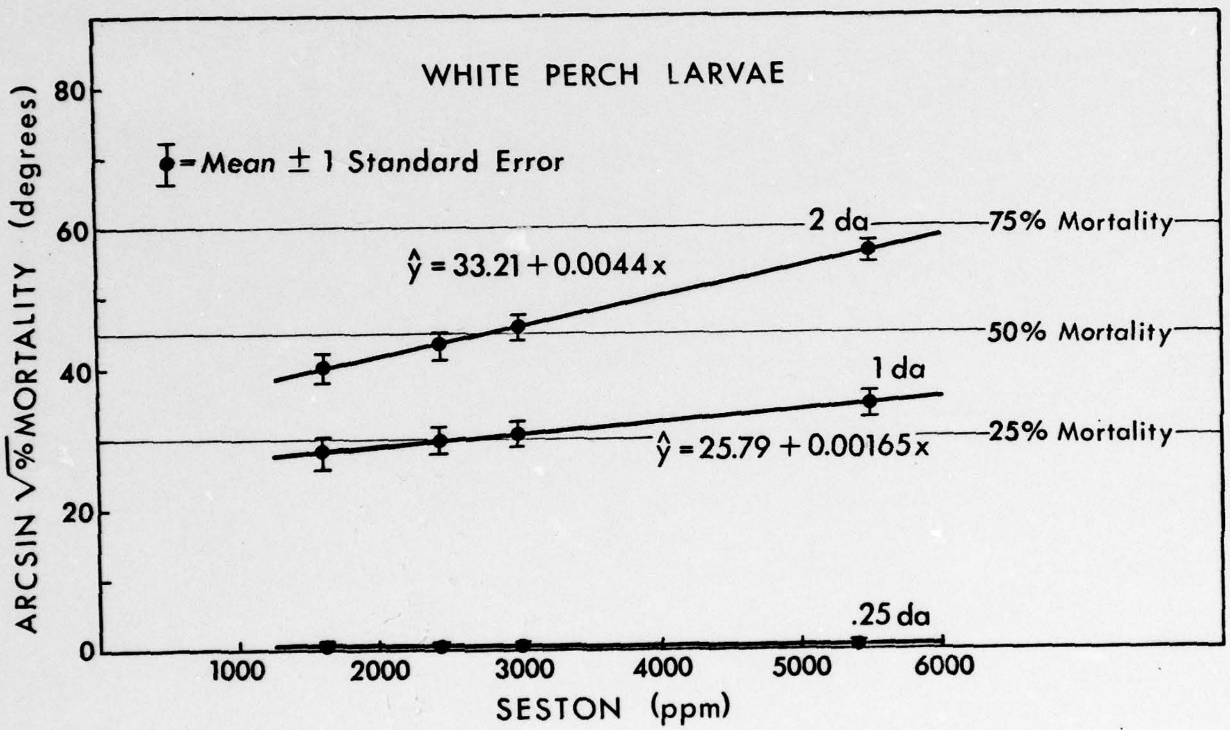

WHITE PERCH LARVAE
= Mean ± 1 Standard Error
2 da
75% Mortality
ŷ = 33.21 + 0.0044 x
50% Mortality
1 da
25% Mortality
ŷ = 25.79 + 0.00165 x
.25 da
ARCSIN √%MORTALITY (degrees)
0
20
40
60
80
1000
2000
3000
4000
5000
6000
SESTON (ppm)

Fig. 5. The effect of various suspended sediment concentrations on the per cent mortality of larval striped bass.

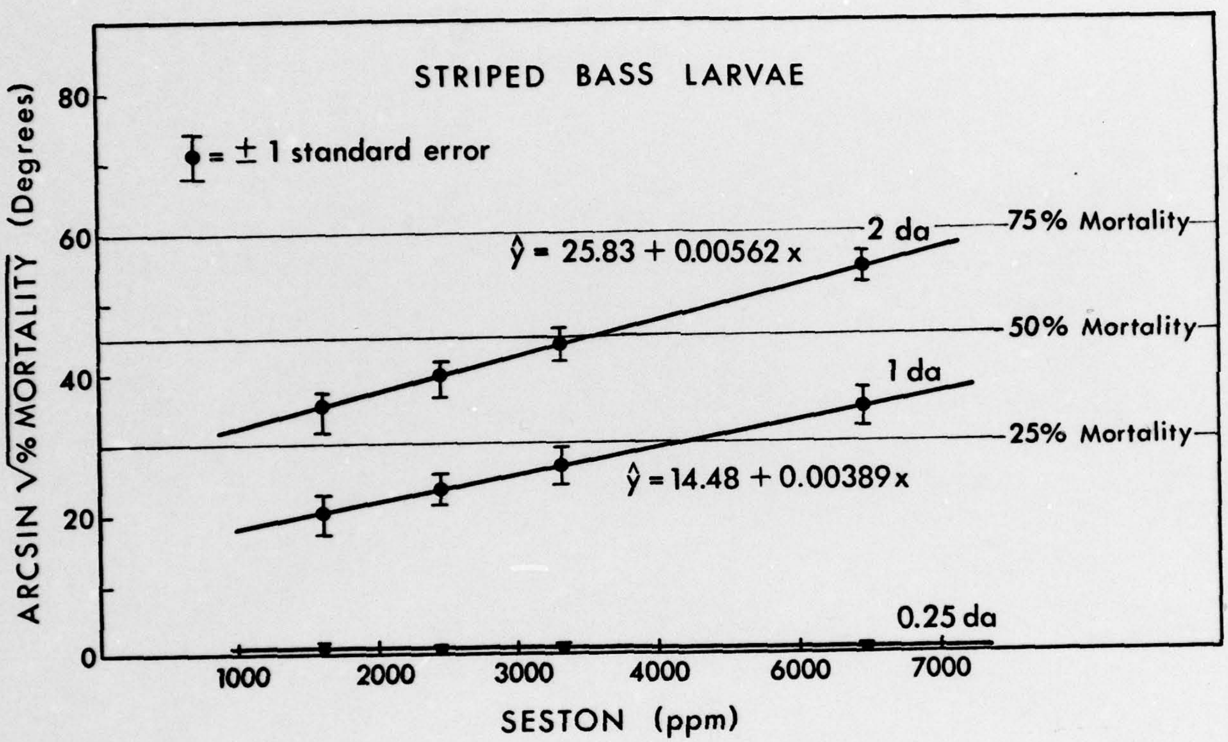
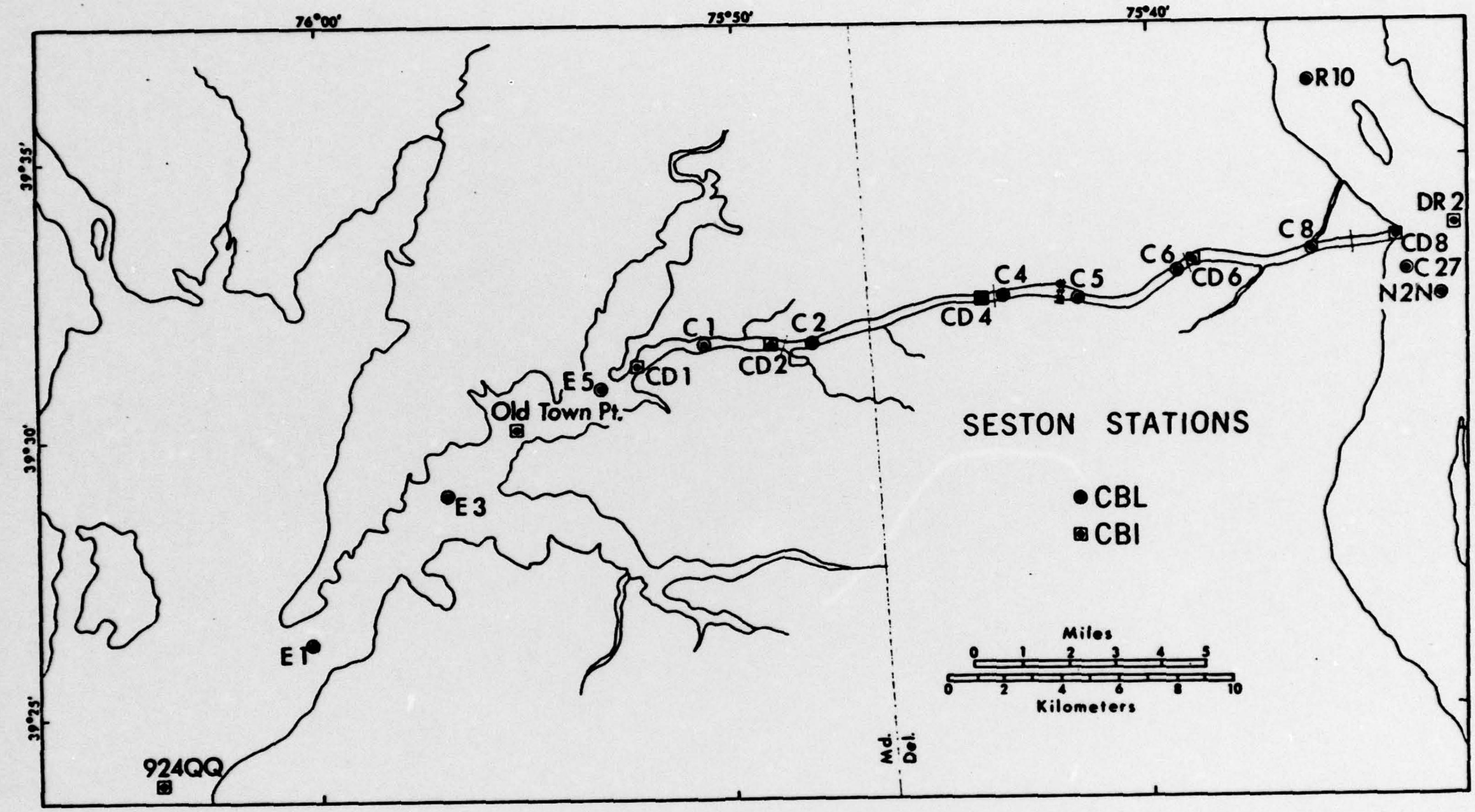

STRIPED BASS LARVAE
= ± 1 standard error
ARCSIN √% MORTALITY (Degrees)
80
60
40
20
0
1000
2000
3000
4000
6000
7000
SESTON (ppm)
2 da
1 da
0.25 da
ŷ = 25.83 + 0.00562 x
ŷ = 14.48 + 0.00389 x
75% Mortality
50% Mortality
25% Mortality

Fig. 6. The location of seston stations of the Chesapeake Bay Institute and Chesapeake Biological Laboratory in the C and D Canal area. Not all CBL stations were sampled at any one time.


76°00'
75°50'
75°40'
39°35'
39°30'
39°25'
R10
DR 2
C 8
CD8
C 27
N2N
C 6
CD 6
C 4
C 5
CD 4
C 1
C 2
CD2
CD1
E 5
Old Town Pt.
E 3
E1
924QQ
Md.
Del.
SESTON STATIONS
CBL
CBI
Miles
0 1 2 3 4 5
0 2 4 6 8 10
Kilometers